STACKED PANEL PROCESSING APPARATUS AND METHODS

Reference to Related Applications

The present invention claims priority to a U.S. Provisional Patent Application, Serial No. 60/271,019, filed February 23, 2001, entitled Stacked Panel Coating and Plating of Printed Circuit Boards.

Field of the Invention

The present invention relates to the processing of panels, such as circuit boards. More particularly, the present invention relates to the processing of panels having at least one through hole.

Background of the Invention

In the printed circuit board industry, many of the processing steps for manufacturing a circuit board are automated, most usually by conveyorizing processing machinery. Printed circuit boards are generally formed from a layer of conductive material, such as copper or copper plated with solder or gold, carried on a substrate of insulating material, such as plastic or fiberglass.

The preparation of a printed circuit board in an automated electroplating system typically requires the plating of conductive metal layers onto the insulating substrate of the board. A circuit board may comprise a copper layer on opposite surfaces of the

insulating substrate (two-sided boards). Alternatively, a circuit board may comprise multi-layer boards having a plurality of inter-leaved parallel planar copper and insulating layers. Through-holes may be drilled in the board and metal plated to create an electrical connection between the circuits formed on the different copper layers.

Summary of the Invention

The present invention provides apparatus and methods for processing panels having at least one through hole. Various examples of application of embodiments of the invention include accomplishing the deposition and electroplating of a metalization product, such as copper, for a circuit board. According to an embodiment of the present invention, a panel stack of circuit boards are processed, allowing simultaneous board processing. A plurality of panels are aligned and stacked such that at least one through hole of the panels provide a continuous open path through the panel stack. In this manner, the coatings and platings of the deposition and electroplating processes are directed to the interior of the drilled holes rather than the panel surfaces. As a result, the present invention can provide savings in cost, time, labor, chemistry and processing equipment.

According to one embodiment, the present invention provides a panel processing apparatus for applying a product to a portion of at least one panel. The panel processing apparatus comprises a housing having a first side and a second side. The second side is adapted to communicate with the panel. The first and second sides define an interior space for delivering the product from the entry port through said interior space to a through hole in the panel. Optionally, the apparatus further comprises a frame oriented

opposite to the second side for supporting the panel. According to various embodiments of the invention, the product may include, for example, products to enable electroless copper deposition, electroplating of copper for a printed circuit board, chemical etchback or desmear, honing of the through hole wall using a slurry of pumice as a replacement for chemical etchback or desmear, chemical microetching of a through hole wall, and through hole blasting with pressurized water or air to clean away any debris.

According to an alternate embodiment, the present invention provides an electroplating apparatus, comprising a first housing having a first side and an interior adapted to fluidly couple to a fluid delivery system, and a frame oriented opposite to the first side of the first housing. The first side of the first housing and the frame are adapted to hold at least one panel having at least one hole and provide fluid from the fluid delivery system through the first housing to pass through the at least one hole. The electroplating apparatus further comprises an electrical connector electrically connected to the panel or panels, and an anode electrically connected to an electrolytic fluid provided by the fluid delivery system and adapted to be electrically connected to the electrical connector to facilitate electroplating of a side of the hole of the panel.

According to another embodiment, the present invention provides a method for applying a product to a plurality of panels. The method includes stacking a plurality of circuit panels together, aligning one or more holes formed in each panel such that the holes are in fluid communication with each other to receive the product, and introducing the product to the through holes of the stacked panels.

According to an additional embodiment the present invention provides a method for applying a metalization product to a panel, comprising providing a housing to sealingly mate with a side of the panel having at least one hole, introducing a metalization product into the housing to travel through the hole, and removing the housing from the side of the panel.

According to an alternate embodiment, the present invention provides a method for electroplating a panel, comprising the steps of providing a housing to sealingly mate with a side of the panel having a direct metalization deposit in at least one hole, providing an electrical connector to electrically connect to the panel, providing an electrolyte within the housing to travel out of the housing via at least one hole, providing an anode to electrically connect to the electrolytic fluid, providing an electrical circuit including the electrical connector and the anode while the electrolyte travels through at least one hole, removing the housing from the side of the panel.

According to yet another embodiment, the present invention provides a method for electroplating a plurality of panels. The method comprises stacking a plurality of circuit panels together, aligning one or more holes formed in each panel such that the holes are in fluid communication with each other to receive a metalization product, providing an electrical connector to electrically connect to the panel, providing an anode to electrically connect to an electrolytic fluid, introducing the metalization product to the holes of the stacked panels, and providing an electrical circuit including the electrical connector and the anode while the electrolyte travels through the holes.

Brief Description of the Drawings

The invention will be apparent from the following description and apparent from the accompanying drawings, in which like reference characters refer to the same parts throughout the different views. The drawings illustrate aspects of the invention and, although not to scale, show relative dimensions.

Figure 1 is an exploded view of a panel processing apparatus according to an embodiment of the invention;

Figure 2 is a cross-sectional view of a segment of a panel stack according to an alternate embodiment of the present invention;

Figure 3 is an exploded view of a panel processing apparatus according to another embodiment of the invention;

Figure 4 is an exploded view of a panel processing apparatus according to a further embodiment of the invention;

Figure 5 is a cross-sectional view of a segment of a panel stack according to an embodiment of the present invention;

Figure 6 illustrates a panel processing apparatus for direct metalization according to an embodiment of the present invention;

Figure 7 illustrates product leakage in a segment of a panel stack for purposes of illustration;

Figure 8 illustrates a set of spring-loaded roller pins for applying pressure to a panel stack according to an illustrative embodiment of the present invention;

Figures 9 and 10 illustrate the use of a pattern plate according to various embodiments of the invention;

Figure 11 illustrates a panel processing apparatus for stacked direct metalization and electroplating according to an illustrative embodiment of the present invention;

Figure 12 illustrates a schematic segment view of the apparatus of Figure 11 for electroplating a panel stack; and

Figure 13 illustrates a variation of the embodiment illustrated in Figure 12.

Detailed Description of the Invention

The present invention provides apparatus and methods for the processing of one or more panels having at least one through hole. Typically, various embodiments of the invention will process a stack of such panels having at least one through hole in each panel configured to provide a fluid path through the panel stack. The types of panels for use with the invention include a wide variety of panels, such as, for example, plastic or fiberglass panels used for the construction of circuit boards.

Through holes in circuit boards are typically from about 0.05 mm to about 5 mm in diameter, although the invention is not so limited. Through holes may initially comprise a nonconductive cylindrical bore. Through holes may also communicate between two conductive surfaces that may be formed along the surface of the circuit board. According to various embodiments of the invention, a conductive material or element may be positioned in the through hole and electrically connected with the conducting sheets or layers to complete an electrical connection between two or more circuit layers.

A panel processing apparatus 5 embodiment of the invention is illustrated in Figure 1. A housing 32 is provided. The housing 32 is adapted for fluid communication with one or more panels forming a panel stack 10. The housing 32 may optionally be provided with a seal along all or a portion of the housing 32 interfacing with the panel stack 10 to form a fluid or gas-tight seal of the housing 32 and a surface of the panel stack 32. The housing 32 may be provided with an entry port 34. It is understood that the illustrative embodiment of Figure 1, and those of other figures, may be inverted or arranged a variety of ways, such as sideways or at an angle, within the scope of the invention.

According to another embodiment of the invention, a location adjustment apparatus 56 may be provided to move the housing 32 relative to a panel stack 10. A variety of devices may be used to form the location adjustment apparatus 56, such as a hoist or winch using a chain, a cable, rope, gears, wheels, pulleys, hydraulic or pneumatic cylinders, or other devices capable of inducing movement, to move the housing 32 and/or panel stack 10. Further examples include the use of rails or guides to define an axis of travel for the housing 32 or panel stack 10. The housing 32 and/or panel stack 10 may than be moved along the axis of travel by the use of a variety of devices, such as a chain, a cable, rope, gears, wheels, pulleys, hydraulic or pneumatic cylinders or other devices capable of inducing movement. These examples are not limiting.

According to another embodiment of the invention, a pump 39 may optionally be provided for creating a pressure differential in the housing 32 by providing or extracting a fluid or gas from the housing 32 via the entry port 34. According to a further

embodiment, a reservoir 50 may optionally be provided fluidly coupled to the housing 32 for providing or storing a fluid or gas for use with the housing 32 via the entry port 34. The reservoir 50 may be used in combination with the pump 39 or may be used without a pump 39. According to an embodiment of the invention, the pump 39 and/or the reservoir 50 may form a fluid delivery system 31 in communication with the entry port 34. In various embodiments of the invention, additional components, such as, for example, additional reservoirs 50, pumps 39 or valves may also be incorporated into the fluid delivery system 31. It is understood that the fluid delivery system 31 may be used to deliver or extract a gas from the housing 32 and that the reservoirs 50 may each be optionally heated or cooled.

According to an embodiment of the invention, a controller 55 is optionally provided. The controller 55 may be in communication with and control the operation of the location adjustment apparatus 56. The controller 55 may alternatively or in addition be in communication with and control the fluid delivery system 31 or any component thereof.

Various embodiments of the present invention may be used for a variety of processes for panels. Examples include chemical etchback or desmear, which are processes used to make sure that all conductive surfaces intersecting a through hole wall are free of any non-conductive residue from drilling, such as plastic or fiberglass, that might interfere with electrical contact with the conductive surfaces. Chemicals used in conventional etchback or desmear procedures, using conventional baths or tanks, can also be used with various embodiments of the invention. Embodiments of the present

invention can process many more panels more quickly, with smaller amounts of chemicals, than conventional procedures.

A further example of a process for use with the invention is honing of the through hole wall using a slurry of pumice as a replacement for chemical etchback or desmear.

Another example is chemical microetching of a through hole wall. When Teflon-based materials are used as the insulating layer of a printed circuit board in place of the more typical fiberglass, etchants known to those in the art can be used with various embodiments of the invention.

An additional example of a use of the invention is through hole blasting with pressurized water or air to clean away any debris left in the holes from the drilling process.

In operation, an embodiment of the panel processing apparatus 5 illustrated in Figure 1 may operate as follows. The panel stack 10, having one or more panels, is located in communication with an interior of the housing 32. The optional location adjustment apparatus 56 may be operated by the use of the optional controller 55 in order to locate the panel stack 10 relative to the housing 32. The optional one or more reservoirs 50 contain the appropriate fluid or gas. Appropriate fluid or gas may include such fluids or gas as those known in the art for performing processes as described herein and others apparent to those of skill in the art.

The optional controller 55 may be used to control the supply of the appropriate fluid or gas into the housing 32 by way of the entry port 34. The optional pump 39 may further be used to provide a pressure differential to the fluid or gas passing through the entry port 34.

The fluid or gas supplied into the housing 32 passes through those through holes in the one or more panels that define a path through the panel stack 10. It is understood that the above process may also operate in reverse, with a fluid or gas administered to a distal side of the panel stack 10 and passing through the through holes of the panel stack 10, through the housing 32. The fluid or gas may then travel through the entry port 34 to the optional reservoir 50, optionally with the assistance of the pump 39.

As used herein, the terms "aligned" or "alignment" are used to describe the configuration of a through hole in each of at least two panels that are arranged so as to form a continuous open path through the panels. Alignment of through holes may be achieved with through holes of differing diameter or with some non-round holes. Furthermore, there is no requirement for the sides of the through holes to form a continuous surface.

While alignment of the through holes such that all corresponding through hole walls form a continuous surface is desirable, it is not necessary. Even if the through holes are not so aligned, as illustrated in Figure 2, provided that there is at least one continuous path 18 through the panels, the liquid or gas will be able to contact the wall surface of the holes in panels 11, 12 and 13 when directed through the hole of panel 11.

A further embodiment of a panel processing apparatus 6 according to the invention is shown in Figure 3. The panel processing apparatus 6 of Figure 3 is similar to the panel processing apparatus of Figure 1, except that a frame 33 is provided as illustrated by way of example in Figure 3 to assist in locating the panel stack 10 relative to the housing 32. The frame 33 may be formed having only sides along a perimeter, or may also be provided with a bottom. The frame 33 may also be provided with a seal for interfacing with the panel stack 10. The location adjustment apparatus 56 may optionally be coupled to move any or all of the housing 32, panel stack 10 and frame 33.

Figure 4 illustrates a further embodiment of the invention. According to this embodiment, a panel processing apparatus 7 is provided similar to the panel processing apparatuses 5, 6 of Figures 1 and 3. The panel processing apparatus 7 of Figure 4 additionally provides an intermediate housing 62. The intermediate housing 62 allows the simultaneous processing of multiple panel stacks 10. As illustrated in Figure 4, a first panel stack 10 may be processed simultaneously with a second panel stack 10a. The intermediate housing 62 can be used to process panel stacks 10 having differing through hole patterns. For example, the panels of first panel stack 10 may have no through holes in locations that would correspond to the through holes of second panel stack 10a. However, because the intermediate housing 62 is located between first panel stack 10 and second panel stack 10a, the fluid or gas being processed through the through holes is able to travel within the open cavity of the intermediate housing 62 to exit from the through holes of the bottom of the first panel stack 10 and travel to the top of the through holes of the second panel stack 10a. As described herein in relation to the housing 32, the intermediate housing 62 may be formed with one or more seals for interfacing with the panels stacks 10, 10a.

Also illustrated in Figure 4 is the use of a further embodiment of the frame 33a. The frame 33a illustrated in Figure 4 is formed similar to the housing 32 so as to allow the optional application of a pressure differential to the bottom of the panel stack 10, 10a or to aid in collection of the fluid or gas processed through the panel stack 10, 10a. The frame 33a may also be provided with a seal for interfacing with the panel stack 10, 10a. The frame 33a illustrated in Figure 4 may be used in combination with any of the embodiments described herein. For example, the frame 33a illustrated in Figure 4 may be used with a single panel stack 10 and/or without the use of the intermediate housing 62, as in Figure 3. An egress port 35 may optionally be provided to allow for entry or exit of fluids or gasses from the frame 33a.

An embodiment of the present invention provides a system and a method for the direct metalization and electroplating of a circuit board. In particular an embodiment provides a system and method for the simultaneous direct metalization and electroplating of a plurality of aligned circuit boards. Those skilled in the art will recognize that an embodiment of the invention can be applied to any treatment of the interior of the holes of a panel, as opposed to the surfaces of the panel, including conventional electroless copper deposition.

Major cost elements in the manufacture of printed circuit boards are the deposition and electroplating of copper. These process steps have the combined purpose of rendering the interior of the drilled holes conductive and then to make use of the conductivity of this coating to further plate a suitable thickness of copper onto the hole walls. Conventional automated electroplating systems consist of machinery for

conveying racks of personal computer (PC) board panels through a series of baths or tanks containing electrolyte in a sequential process in order to accomplish the plating of the circuit boards. Electroplating involves coating a conductive layer, such as copper, on the nonconductive through hole bore to provide a cylindrical bridge between the conducting sheets on the opposite ends of the through hole. Prior to the electroplating process, a through hole must first be treated with a conductive material to make the hole surface amenable to electroplating. The preparation process generally comprises either conventional electroless copper deposition or the increasingly more current direct metalization.

Direct metalization consists of the use of a carbon or graphite-based product to coat the inside of the drilled holes in a circuit board with a sufficiently conductive layer so as to allow the eventual electroplating of a thicker metalization product layer, such as a copper layer, onto the walls of the holes. The conductive direct metalization coating is preceded by one or more cleanings and rinsing steps and is followed by, first, a drying step to dry the carbon or graphite product and second, by a micro-etching of the copper which releases the carbon or graphite product from the copper surfaces, leaving it only where required, namely, on the plastic surfaces of the hole walls.

In conventional conveyorized systems, the copper surfaces of the boards, as well as the through holes, are exposed to and coated with the cleaner, direct metalization product and electroplating product. The excess products must then be removed from the copper surfaces of the boards. Thus, a large portion of the cleaner and direct metalization product is wasted by coming into contact with the copper surfaces of the panels being processed rather than solely with the surface of the hole walls. In addition,

conventional systems require large conveyor belts for sequentially processing each board in a time-consuming, multi-step preparation process.

According to an embodiment of the present invention, the direct metalization process and the electroplating process are facilitated by stacking a plurality of circuit boards such that the holes of the circuit board are in alignment in order to process a number of boards simultaneously.

Figure 5 illustrates a segment of the panel stack 10 of three panels 11, 12, 13 being fabricated according to an embodiment of the present invention. Each panel comprises a core 16 comprised of fiberglass, plastic or another insulating material, a top coating 17 comprised of copper or other suitable material, and a bottom coating 19 also comprised of copper or other suitable material. According to an embodiment of the present invention, the panel stack 10 may comprise any number of panels. According to an embodiment of invention, the panels may be stacked such that the drilled through holes 15 of the panels are in alignment, providing a fluid communication path 18 between the panels. Cleaner, rinse fluid, direct metalization product and air are introduced in sequence into the through holes to simultaneously prepare all three panels 11, 12, 13 for electroplating. In this fashion, the chemical products being used are primarily directed to the through hole walls, and are inhibited from contact with the top or bottom surfaces of the panels. It is noted that the top surface of the top panel and the bottom surface of the bottom panel may be in contact with the chemical products in some embodiments of the invention. As a result, the chemistry products may be used with greater efficiency, with limited chemistry products wasted by contacting surface areas of the panels that do not require direct metalization or electroplating.

Figure 6 depicts a direct metalization apparatus 30 according to an embodiment of the present invention for applying a selected metalization product to the wall of a through hole in a circuit board. The apparatus 30 allows the succession of cleaner, rinse, direct metalization product, and air from a fluid delivery system 31 to be sequenced through at least one through hole of a circuit board. The housing 32 is provided for communication with the panel stack 10. The housing 32 may be formed as an upper plenum 32. The frame 33a is also provided opposite the housing 32, illustrated as a lower plenum 33a. The upper plenum 32 is positioned above the panel stack 10 and has the entry port 34 for receiving the products from the fluid delivery system 31 for the direct metalization process of the panel stack. An optional lower plenum 33a may be situated below the stack of panels 10, and includes an egress port 35 for draining away the various products from the panel stack 10. According to an illustrative embodiment, the lower plenum 33a is selectively moveably coupled to the upper plenum and/or panel stack 10 by the optional use of the location adjustment apparatus 56 to vary the distance between the upper and lower plenum and/or panel stack. In this manner, direct metalization apparatus can accommodate a variety of sizes of panels stacks and the panel stack can comprise any number of panels. The edges of the plenums 32, 33a may include seals 36, illustrated as O-rings, to sealingly contact the panel stack and thus inhibit leakage of the chemistry. According to an alternative embodiment, adapter frames with O-rings, inserted 32, 33a, are used to adapt the system to smaller panel sizes. As shown in Figure 7, the stack of panels 10 is placed in the housing between the upper plenum 32 and the lower plenum 33a. According to one embodiment of the invention, the upper plenum 32 and lower plenum 33a are clamped so as to bring the plenums closer together against the panel stack 10.

According to the present invention, the fluid delivery system 31 initializes the direct metalization process by pumping cleaner from a reservoir 38 through a first valve 37 and into the upper plenum 32. The cleaner then passes through at least one through hole of the panel stack. Pump 39 provides a sufficient negative pressure differential to enhance the flow of the cleaner and assure passage of the cleaner through the through hole. While a pressurized flow is preferable, gravity is also sufficient for effecting a flow through the though holes.

According to the present invention, the panel stack may contain between one and a hundred or even more panels. Provided that there is a through hole path through the panel stack, there is virtually no limit to the number of panels being processed at one time.

After the cleaner drains away through egress port 35 on the lower plenum 33a, an analogous step is performed using a rinse fluid, such as water, to rinse away the cleaner. The rinse fluid is pumped from a rinse fluid reservoir 40, through a second valve 41 and into the upper plenum 32. The rinse fluid flows through the one or more through holes in the panel stack and drains through the egress port 35. If necessary, the cleaner and rinse steps are repeated any number of times.

The rinsing step is then followed by a direct metalization step, where a direct metalization product, such as a carbon or graphite-based product, is similarly pumped from a reservoir 42 through a valve 43 and finally through the through holes. The direct metalization product coats the interior surfaces of the holes in the panel stack. Finally,

air 45 is introduced to dry the direct metalization product material left on the walls of the holes.

According to an embodiment of the invention, the air 45 may optionally be heated. The system further includes a valve controller and timer 44 to regulate each step in the described process. According to an illustrative embodiment, the cleaner, rinse fluid, and direct metalization product are recycled. After each product exits the lower plenum, a set of valves 37a, 41a and 43a direct each product to the respective reservoir. Upon completion of the deposition process, the individual panels in the panel stack are ready to be cleaned in preparation for imaging. If the panel stack is to be electroplated in stack form as described below, then the stack is not disassembled at this stage.

According to an illustrative embodiment, alignment of the panel stack can be accomplished by pinning the individual panels together using one or more alignment holes along the panel edges, provided for that purpose. According to this embodiment, the alignment holes of all of the panels in the panel stack are aligned, and one or more alignment rods are inserted into the alignment holes to secure the position of each panel relative to the other panels in the panel stack.

However, as shown in Figure 7, holding the panels together only along the edges may allow for some leakage of chemistry into a gap 49 between the intervening copper surfaces 47, 48 of the panels, thereby compromising the efficiency of the stacked panel coating process. To attain the full potential of the direct metalization process of the present invention, means are provided for applying pressure to the panel stack 10 from above and below, thus inhibiting the occurrence of gaps 49. According to one

embodiment, illustrated in Figure 8, application of additional pressure to the stack of panels toward the center and throughout the stack surface is provided to maximize the efficiency of the deposition system illustrated in Figure 6. The application of pressure by means of a pressure pin ensures a compact panel stack and inhibits leakage of chemistry between individual panels. As illustrated, according to one embodiment, spring-loaded pressure pins 51 may be used to apply pressure from above and below the stack 10. According to one embodiment, the pins 51 need only be several inches apart, relying on the mechanical stiffness of the individual panels to maintain the absence of gaps between panels. According to one embodiment the spring-loaded pressure pins 51 are positioned to ensure that no pins cover any holes in the circuit board, as a blocked hole would prevent the deposition chemistry from entering the holes. According to the illustrated embodiment, the pressure pins 51 may optionally further include rollers 52 contacting the top and bottom surfaces of the panel stack. The pressure pins are slidably coupled to the upper and lower plenum, and the rollers 52 allow the pressure pins to move slightly back and forth on the surfaces. In this manner, the rollers 52 ensure that no holes are permanently blocked while the chemistry is being introduced and drained from the drilled holes in the panel stack 10.

The present invention can optionally include a pattern or "dummy" plate. According to one embodiment, the pattern plate can be sized to cover the top panel in the stack. The pattern plate is formed so that at least one hole corresponds to and is aligned with the through holes in the panel stack. Figures 9 and 10 illustrate the use of a pattern plate 75. The pattern plate can be mounted to the bottom surface of the upper plenum 32, or mounted on top of the panel stack 10. In this manner, the pattern plate 75 protects the upper surface of top panel in the stack from exposure to the chemical

products of the direct metalization and electroplating process. As shown in Figure 9, the pattern plate 75 may optionally also be used to prevent processing of some through holes.

While the panel stack being processed in the manner described above consists of like panels with holes in alignment, the system and apparatus can be extended to accommodate several panel stacks, each containing a different set of one or more panels and therefore a different distribution of holes. By optionally stacking several of the housing 32, panel stack 10 and frame 33a assemblies previously described one on top of the other, or by the use of an intermediate housing 62, a tower consisting of several groups of panels can be processed at one time. Hundreds of panels can be processed in this manner in a matter of minutes.

Referring to Figures 11 and 12, the apparatus illustrated in Figure 6 and described above for stacked direct metalization can be modified to provide the subsequent electroplating of the panel stack through holes in the preparation of circuit boards as well. Figure 11 illustrates a direct metalization and electroplating apparatus 60 according to the present invention. The apparatus 60 includes many of the same features as the apparatus 30 of Figure 6, and further includes an electroplating system. After direct metalization, as described above, or electroless deposition, the holes of the circuit board are ready to be electroplated by pumping electrolyte from an electrolyte reservoir 65 through the through holes in a process similar to the processes wherein other chemistry is introduced to the through holes in the direct metalization example described above, utilizing a pump 39 and a valve controller and timer 44. A valve 66 corresponds to the electrolyte reservoir 65 and controls the flow of electrolyte from the

reservoir. According to a preferred embodiment, the upper plenum 32 and the lower plenum 33a are flooded with electrolyte fluid during the electroplating process by the use of the fluid delivery system 61. The term "electrolyte" refers to any liquid or solid substance that while in solution or in its pure state will conduct an electric current by means of the movement of ions. Typically, an electrolyte is a solution of water and acids or metal salts.

Electroplating requires an electrical connection to the through holes of the panels. One embodiment of the invention the present invention, illustrated by way of example in Figure 12, provides an electrical connector 73 electrically connected to the panel stack 10 and an anode 72 electrically connected to an electrolytic fluid 71. This embodiment of the present invention provides a continuous electrical path from the panel stack 10 through the electrolyte 71 to an anode 72, such as a copper anode. An electrical voltage is impressed between the positive anode 72 and the panel stack 10. The panel stack is connected via the electrical connector 73 to a cathode 74 to induce a negative charge on the panel stack 10. In this embodiment of Figure 12, the panel stack 10 is immersed in an electrolytic bath 71 between the housing 32 and frame 32a.

The panels are held in an apparatus of the type previously described with reference to Figures 3, 4, 6 and 11 in order to hold the stack together and to allow plating solution to be pumped through the holes. Optional pumping of electrolyte assures a continual supply of fresh plating solution to be in contact with the hole walls. There are several methods for establishing an electrical connection to the panel stack, ensuring that each panel is connected to the source of electrical current. For panels prepared for plating by direct metalization, a preferred method of plating comprises

connecting an electrical connector 73, such as a conductive brush or rubber, to the individual panels, as illustrated in Figure 12. The conductive brush or rubber is pressed against the panel edges to establish an electrical connection. By contacting an exposed copper edge at an edge of each panel of the panel stack, an electrical connection is made to each individual panel. According to an illustrative practice, the electrical connector 73, such as the conductive brush or rubber, runs the length of the stack edge to ensure that there is sufficient opportunity for the connector 73 to contact every panel in the stack 10. Alternatively, for panels prepared for plating by electroless deposition, connection to the stack of panels can be as simple as connecting to metallic alignment pins or pressure pins used to hold the stack together.

It is important to note that despite the total combined length of the superimposed holes of the panel stack, which may be several inches, stacked deposition and electroplating method of the present invention is unlike attempting to plate a hole of a similar depth in a single panel, in which a much higher throwing power would be required to accomplish the task. In the case of the stacked panels of an embodiment of the present invention, individually connected electrically plating within the holes occurs as efficiently as if each panel were separately processed in individual plating tanks.

As plating current is introduced at each panel surface via the connector 73, such as a conductive brush, each hole may receive a plating current as if each panel was in an individual plating tank. According to an embodiment of the invention, electrolyte is provided throughout the plating process. The pump 39 can be configured to recirculate the plating solution to the stack structure through valve 67 after the electrolyte exits the lower plenum. Optionally, recirculation can be continuous. Since the only plating

current required is that needed to plate the holes, and not the panel surfaces, the power requirements for electroplating are vastly reduced by implementing the teachings of the present invention. While there may be some preferential plating in the holes at the top and bottom of the stack of panels, a uniformity of plating through the entire stack may be achieved by providing optional additional plating current to the center of the stack as opposed to the top and bottom extremities. According to one embodiment of the invention illustrated in Figure 13, uniform plating is accomplished through the use of several connectors 73, such as brushes, which bring additional current to the desired portions of the panel stack. Desired portions may include, by way of example, the panel stack center and/or the stack top so as to reach the uniformity required. Optional circulation of plating solution to the holes further aides in the removal of any gas bubbles or debris that can potentially interfere with the plating or direct metalization processes.

An embodiment of the present invention provides improved manufacture and preparation of circuit boards. In conventional systems, a large portion of the cleaner and direct metalization product is wasted by coming into contact with the copper surfaces of the panels being processed rather than solely with the surface of the through hole walls. Since, on average, the area of panel surface is roughly ten to twenty times the area of the totality of the through hole walls, in conventional systems, most of the chemistry is either used up or wasted on surfaces which need not be coated. According to the present invention, the cleaner and direct metalization product are introduced primarily to those surfaces requiring them, such as, for example, the hole walls, resulting in a savings in chemistry costs on the order of 90 to 95% in some applications.

Various embodiments of the invention provide improvements similar to those for direct metalization in the electroplating of stacked panels, in that plating of copper can be directed primarily to the through hole walls, inhibiting copper plating from occurring on the panel surfaces. This preferential plating of the holes as compared to the panel surface reduces the amount of copper that must be etched away if panel plating is used or else allows a tent and etch process, a simpler and faster process than pattern plating without increasing the level of waste treatment involved with plating the entire panel. As the panel surfaces are not substantially exposed to the plating solution, there is no need for the various cleaning and microetching steps which normally prepare the panels for electroplating.

According to an embodiment of the invention, a larger number of panels can be metalized and electroplated simultaneously than is currently possible in conventional electroplating tanks. Furthermore, the embodiments illustrated and described herein can have a smaller footprint than a conventional metalization and electroplating apparatus and be less costly to build and maintain than the current conveyorized systems that are used for direct metalization. Finally, since there are less wasted cleaner and direct metalization product, there are also fewer problems associated with waste treatment.

Various other configurations are possible, horizontally, vertically and other angles, as well as other means of pressing the panel stack together across the end surfaces of the stack. The present invention provides for the processing of a panel stack with at least one through hole in alignment, thereby allowing the various chemistries to be employed with maximum efficiency and minimal waste.

These embodiments and examples are meant to be illustrative and not limiting. The present invention has been described by way of example, and modifications and variations of the exemplary embodiments will suggest themselves to skilled artisans in this field without departing from the spirit of the invention. Features and characteristics of the above-described embodiments may be used in combination. The embodiments, including preferred embodiments, are merely illustrative and should not be considered restrictive in any way. The scope of the invention is to be measured by the appended claims, rather than the preceding description, and all variations and equivalents that fall within the range of the claims are intended to be embraced therein.

Having described the invention, what is claimed as new and protected by Letters Patent is: